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Effect of heat shrinkable film on storability of Citrus cv. Assam Lemon [*Citrus limon* Burm.f.] under ambient conditions

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Abstract
A study was conducted to observe the effect of heat shrinkable films on shelf-life and quality of Assam Lemon [*Citrus limon* Burm.f.] stored under ambient conditions. Fully mature green Assam Lemon fruits collected from Orchard of the College of Horticulture & Forestry, Pasighat were subjected to three treatments *viz*. T_1(Individual Shrink wrapping), T_2(Shrink Wrapping in trays), T_3(Control treatment) and were stored in ambient condition (29-32ºC temperature with 55-78% relative humidity). Observations on PLW, TSS, titratable acidity, sensory quality, colour and marketability were recorded. Results revealed that heat shrinkable films influenced the quality parameters of Assam Lemon during storage. However, considering the physical and quality parameters, it was found that T_1(Individual Shrink wrapping) was the superior treatment having high marketable fruits, low physiological loss in weight (3.924%), better retention of colour, TSS(4.23ºBrix), titratable acidity(4.93%) with better sensory score as compared to T_2 (Shrink Wrapping in trays) and T_3 (Control treatment). The investigation revealed that Lemons could be stored up to 30-35 days when individually packed in heat shrinkable films with least PLW while maintaining the fruit quality at the same time under the ambient room temperature which can be recommended for Assam Lemon growers.

Keywords: Assam lemon, shrink wrapping, PLW

Introduction
Assam lemon a principle lemon cultivar of North Eastern Region of India, which belongs to family Rutaceae have originated in the Eastern Himalayan Region and its adjoining areas Especially Indo-Burma regions are considered as host of diverse *Citrus* species (Singh and Singh 2006) [18]. Lemon is popularly seen in kitchen gardens. In India, fresh lemons are primarily consumed for a cooling effect in summers. It is widely used in preparation of soft drinks and possesses special dietary and medicinal value associated with its high vitamin C content and also used as natural herbal shampoo by boiling it fruit peel and fresh leaves along rice water (Singh *et al*. 2014) [13, 19]. Lemon oil is among the most important citrus oils used for flavouring soft drinks, baked foods, confectioneries, etc. Besides, it is also used for preparing pickles, squashes, jams, jellies and marmalades. The plant is endowed with the trait of bearing fruits in several flushes, thus making it available throughout the year (Savreet, 2013) [17]. The distribution of Assam lemon in NorthEast India includes Assam, Arunachal Pradesh, Nagaland, Meghalaya and Mizoram (Singh and Singh 2006) [18]. In India, limes and lemons are collectively occupies an area of 2.86 lakh hectare with an annual production of 28.35 lakh ton and having a productivity of 9.9 t/ha. (Anon, 2015) [1]. Under tropical conditions limes, lemon and citron flower almost throughout the year, whilst spring (February – March) is the main blooming period (Bhattacharya and Dutta, 1956) [6]. However, in Assam and subtropical condition of Arunachal Pradesh including East Siang district most of the lemons flower round the year but it main peak flowering during Jan-Feb for summer season fruit and September-October for winter season fruit (Mahesha, 2016) [15].
Shelf life in Assam lemon can be regulated by adopting various horticulture practices like wrapping individual as well as tray wrapping practices of desired season. There is an imperative need for improvement of fruit quality in order to meet the change in market demand and making it available to the maximum extent by wrapping as post harvest treatment practices. Although the fruit are available throughout the year, it peak harvest season are Jan-Feb for winter season crop and June-July for rainy season crop. Keeping these in view, an attempt has been made to evaluate the **e**ffect of different wrapping technique in Assam Lemon for the extension of shelf life under the Pasighat condition of Arunachal Pradesh, India.

Materials and Methods

Experimental site

The present investigation was undertaken in the College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh, under the Department of Post Harvest Management during the period from August to September 2017.

Raw materials

Freshly harvested, green mature Assam Lemon free from blemishes obtained from the Orchard of Fruit Science Department, College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh were used for the experiment. Precautions were taken while handling the produce to minimize abrasions and bruising which leads to accelerated spoilage and rotting.

Preparation of samples

Mature green lemons of uniform size were washed with tap water to remove the dirt and then surface dried at room temperature by spreading it in blotting paper for 20-30 minutes. The lemons were then subjected to the following treatments *viz*. T_1-Individual wrapping with heat shrinkable film (15µ); T_2-Tray overwrapped with heat shrinkable film (15µ); T_3-No wrapping (open condition). The lemons in heat shrinkable films were passed through a shrink wrapping machine (Chamber machine: 15X20) at 350º C for 3 seconds. The lemon fruits in different packages were stored in cool, dry place on racks at room temperature in the laboratory of the Department of Post Harvest Management during the period from August to September, 2016. The average temperature and relative humidity during storage period varied from 29 to 32ºC and 55 to 78% respectively.

Observation

Physiological loss in weight (%)

Assam Lemon fruits were weighed initially and at 2 days intervals during storage. The results were expressed as

$$\text{PLW (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Colour

Change in skin colour was rated at interval of 5 days during storage using a hedonic scale of 1 to 5 as given below: 5= Uniformly green, 4= More green than yellow, 3= Equally green and yellow, 2= More yellow than green, 1=Uniformly yellow.

Total Soluble Solids: The total soluble solids (TSS) of the fruit juice were determined using a hand refractometer and expressed as per cent TSS after making the temperature correction at 20 ºC.

Titratable Acidity: The titratable acidity as percent citric acid of the Juice was determined, using the method described in AOAC (1995) [2].

Sensory quality

The visual quality of the packaged produce was assessed by adopting a hedonic scale from 1 to 9, rating with 9=excellent, no visual defects, 7=good minor defects, 5=fair moderated defects, 3=poor moderately severe defects, 1=unusable. In this study, score of 6 is considered as the marketable limit for a fresh produce (Lopez-Galvez *et al*., 1997) [12]. The assessment was carried out at the beginning of the experiment and on the 5th, 10th, 15th, 20th, 25th and 30th day of storage.

Marketability (%)

The number of fruits acceptable by consumer in each experimental lot on the day of observation was recorded and expressed in percentage (Assumi *et al.*, 2009) [3].

Statistical Analysis

The statistical analysis of various characters studied in this experiment was carried out as per the procedure appropriate to the design of experiment i.e. 2 factor factorial Completely Randomized Design by adopting the Statistical procedures given by Gomez and Gomez (1984) [8].

Results and Discussion

PLW

A significant ($p< 0.05$) difference in weight loss was observed among the packed and unpacked lemons which increases with advancement of storage period. However, the lemons packed individually in heat shrinkable films show the lowest weight loss (3.924%) compared with the tray packed ones (6.941%) on the 32nd day of storage (Table 1). The PLW for the unpacked lemons were as high as 41.3% on the 14th day of storage. The lower weight loss in T_1 might be due to increase in CO_2 concentration, low oxygen atmosphere and decrease in transpiration rate due to higher RH inside (Wang 1977; Gorini and Uncini 1981; Mercado *et al.* 1995) [20, 9, 16]. Reduction in PLW or decay loss may primarily be due to creation of modified atmosphere around the fruits by the gas permeability properties of shrinkable films (Ben-Yehoshua, 2005; Ben-Yehoshua *et al.*, 1983) [5]. Ladaniya and Singh (2001) [10] in Mosambi Sweet Orange and Ladaniya *et al.* (1997) [11] in Nagpur Mandarin have also reported such trends in PLW and decay in citrus fruits following shrink-wrapping. Condensation of water droplets was observed in overwrapped trays.

TSS

The total soluble solids (TSS) of wrapped and unwrapped fruits were observed to increase during storage (Table 2). Lowest TSS (4.23^{O}Brix) was observed in T_1 [Individual wrapping with heat shrinkable film (15µ)] followed by T_2 [Tray overwrapped with heat shrinkable film (15µ)] with 4.43ºBrix and T_3 [No wrapping] with 5.96 ºBrix on the 30th day of storage. Increase in TSS could be as a result of the breakdown of organic polymers into simple sugars (Faasema *et al*., 2011 [1] and Mahajan & Singh, 2014) [13, 19].

Titratable acidity

The titratable acidity of fruits decreases during storage irrespective of the packaging treatments (Table 3). T_1 has the highest acidity of 4.93% on the 30th day of storage followed by T_2 with 4.737%. Generally organic acids usually decline during ripening of fruits as they are used as substrates for respiration or converted into sugars and their further utilization in the metabolic process of the fruits (Faasema *et al.*, 2011) [1]. In shrink wrapped fruits the lowering of acidity was delayed which might be due to the effect of shrink packaging film in delaying the respiratory and ripening process (Mahajan *et al.*, 2013) [14].

Colour & Sensory quality

There was better retention of green colour in individually wrapped lemons with a score of 2 even upto 25th day of

storage as compared to tray wrapped lemons with the same score on 20th day of storage (Table 4). However the open condition was totally yellow with a score of 1 even on 10th day of storage. Thus, T_1 had a better retention of green colour followed by T_2 and T_3. T_1 had a good sensory score of 7 even on the 30th day of storage (Table 5). However T_2 and T_3 had a score of 3 and 1 on the 30th day of storage.

Marketability

Marketability of T_1 [Individual wrapping with heat shrinkable film (15µ)] was as high as 66.67% on the 30th day of storage while T_2 [Tray overwrapped with heat shrinkable film (15µ)] with 53.33% on the 25th day of storage (Table 6). Marketability of T_3 [No wrapping] was as low as 43.33% on the 20th day of storage.

Table 1: Physiological loss in weight (%) of lemon as affected by wrapping at different days of storage in ambient condition

Treatment	Days of Storage															
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32
T_1	0.26	0.26	0.52	0.77	1.23	1.51	1.77	2.07	2.14	2.46	2.74	2.88	3.06	3.25	3.74	3.92
T_2	0.42	0.81	1.16	1.45	2.07	2.62	2.95	3.45	3.87	4.21	4.78	5.13	5.37	5.84	6.33	6.94
T_3	7.12	13.77	18.54	23.57	31.57	37.27	41.34	51.24	59.37	62.43	73.16	77.43	87.09	95.33	101.97	113.33
Mean	2.60	4.94	6.74	8.60	11.62	13.80	15.36	18.92	21.79	23.03	26.89	28.48	31.84	34.81	37.34	41.39
SEM±	0.011	0.016	0.010	0.009	0.011	0.006	0.001	0.018	0.009	0.013	0.012	0.008	0.027	0.016	0.006	0.015
CD@5%	0.03	0.04	0.03	0.02	0.03	0.01	0.05	0.06	0.02	0.04	0.03	0.02	0.10	0.04	0.01	0.04

T_1-Individual wrapping with heat shrinkable film (15µ); T_2-Tray overwrapped with heat shrinkable film (15µ); T_3-No wrapping (open condition)

Table 2: TSS (°Brix) of lemon as affected by wrapping at different days of storage in ambient condition

Treatment	Days of Storage						
	0	5	10	15	20	25	30
T_1	4.0	4.0	4.000	4.067	4.133	4.167	4.233
T_2	4.0	4.0	4.000	4.033	4.133	4.233	4.433
T_3	4.0	4.0	4.167	4.967	5.367	5.767	5.967
Mean	4.0	4.0	4.05	4.35	4.54	4.72	4.87
SEM±	--	--	0.022	0.038	0.038	0.038	0.038
CD@5%	NS	NS	0.067	0.115	0.115	0.115	0.115

T_1-Individual wrapping with heat shrinkable film (15µ); T_2-Tray overwrapped with heat shrinkable film (15µ); T_3-No wrapping (open condition).

Table 3: Titratable acidity (%) of lemon as affected by wrapping at different days of storage in ambient condition

Treatment	Days after storage						
	0	5	10	15	20	25	30
T_1	5.643	5.570	5.503	5.420	5.310	5.117	4.930
T_2	5.590	5.513	5.507	4.893	4.880	4.857	4.737
T_3	5.610	5.513	5.403	4.890	4.913	4.710	4.600
Mean	5.61	5.53	5.47	5.06	5.03	4.89	4.75
SEM±	--	0.009	0.008	0.006	0.007	0.005	0.006
CD@5%	NS	0.027	0.026	0.018	0.021	0.015	0.018

Table 4: Colour of lemon as affected by wrapping during different days of storage in ambient condition

Treatment	Days of Storage						
	0	5	10	15	20	25	30
T_1	5	5	5	4	3	2	1
T_2	5	5	4	3	2	1	1
T_3	5	3	1	1	1	1	1

5= Uniformly green, 4= More green than yellow, 3= Equally green and yellow, 2= More yellow than green, 1=Uniformly yellow

Table 5: Sensory quality of lemon as affected by wrapping during different days of storage in ambient condition

Treatment	Days after Storage						
	0	5	10	15	20	25	30
T_1	9	9	9	9	7	7	7
T_2	9	9	7	7	7	5	3
T_3	9	7	7	5	3	3	1

9=excellent, no visual defects, 7=good minor defects, 5=fair moderated defects, 3=poor moderately severe defects, 1=unusable

Table 6: Marketability (%) of lemon as affected by wrapping at different days of storage in ambient condition

Treatment	Days after Storage						
	0DAS	5DAS	10DAS	15DAS	20DAS	25DAS	30DAS
T_1	100	100	100	96.67	86.67	76.67	66.67
T_2	100	100	100	76.67	66.67	53.33	43.33
T_3	100	100	79.67	56.67	43.33	30.00	26.67

Mean	100	100	93.22	76.66	65.55	53.33	45.55
SEM±	--	--	0.666	11.535	11.535	9.419	11.535
CD@5%	--	--	0.111	3.845	3.845	2.354	3.845

T_1-Individual wrapping with heat shrinkable film (15µ); T_2-Tray overwrapped with heat shrinkable film (15µ); T_3-No wrapping (open condition); DAS-Days after storage.

Conclusion

Considering all the physical and quality parameters, it was found that T_1(Individual Shrink wrapping) was the superior treatment because of high marketable fruits, low physiological loss in weight (3.924%), better retention of colour, TSS(4.23°Brix), titratable acidity(4.93%) with better sensory score followed by followed by T_2 (Shrink Wrapping in trays) and T_3 (Control treatment). Therefore, it can be recommended to the growers of Citrus cv. Assam Lemon to increase the shelf life up to 30-35 days by packing individually in heat shrinkable films with least PLW and maintaining marketable quality of the fruit for better income generation.

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